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Cooling of Hands and Fingers Wetted by Snow

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Summary

While working with bare hands in winter, hands and fingers get often contact with loose snow. The snow then attaches to the skin and melts quickly, which causes rapid cooling. However, the effect of snow cooling is not quantified. In this study the effect of ca. 2 s immersion of hand into pulverized snow on subsequent hand and finger temperatures at –10 °C and 2.0 m/s wind were studied. Non-immersed hand was used as a reference. After the snow immersion, the immersed and non-immersed hands were exposed to wind for 3 min. In the non-immersed hand, the skin temperatures in fingers decreased in 3 min to 12.4 - 15.2 °C and in hand to 19.4 - 22.7 °C. In the immersed hand, finger temperatures were 6.1 - 8.4 °C lower than in the non-immersed hand, measured 30 s after the immersion. At the end of the 3 min cold exposure, the temperatures in the different sites of the immersed hand were still 2.9 - 7.0 °C lower than without immersion. The results emphasise the marked cooling effect of single snow immersion on hand and especially on finger temperatures. Snow immersion markedly increases the risk of frostbite.

Introduction

Military tasks must often be performed with bare hands to be able to handle small objects. Complaints of cold pain or numbness have often been recorded. Our recent winter measurements show especially low finger temperatures while training with mortars, while rifle shooting, using keyboards of communication systems and handling metal dishes even at relatively high ambient temperatures (at -5 - 0 °C).

Exposing bare hands to cold increases radiative, conductive (contact cooling) and convective (wind chill) heat loss, and if the hands are wet, also evaporative heat loss. There are methods to predict finger cooling caused by convective (e.g., Oakley 1990) and conductive heat loss (e.g., Chen et al. 1996, Rintamäki and Rissanen 1997, Den Hartog et al. 2000). However, bare hands are often unintentionally in contact with snow, or even immersed in snow, which can increase heat loss at the same time due to contact cooling, due to the heat required for the thawing of snow, and due to increased evaporation. To our knowledge, there is no information about the effect of snow immersion on hand and finger temperatures.

The aim of this study was to quantify the effect of snow immersion on hand and finger temperatures.

Paper presented at the RTO HFM Symposium on "Blowing Hot and Cold: Protecting Against Climatic Extremes", held in Dresden, Germany, 8-10 October 2001, and published in RTO-MP-076.

Material and Methods

Four men, aged 34 - 47 years were exposed to cold. With ca. 2.5 clo clothing the thermoneutral subjects entered the wind tunnel (–10 °C and 2 m/s wind), removed mittens and immersed one hand into soft pulverized snow (natural snow, less than 24 h old) for ca. 2 seconds so that the hand up to the wrist was thoroughly in contact with snow. Immediately after the immersion, the hand was shaken briskly to remove melted and non-melted snow, but the hand was not dried otherwise. After that the test subjects stood for 3 min in the wind tunnel, fingertips towards the wind. Then the subjects moved to 21 °C, and the rewarming was recorded for 10 min. Skin temperatures of forefinger (palmar and dorsal sides, the first phalanx), little finger (palmar side, the first phalanx) and hand (palmar and dorsal sides) were recorded at 10 s intervals with YSI 409b thermistors and Squirrel 1200 datalogger. The test was repeated 3 days later with another hand immersed in snow.

Results

After the 3-min cold exposure, the skin temperatures without snow immersion were in little finger 13.2 ± 1.2 °C (mean ± SE, n = 8) (figure 1), in forefinger 15.2 ± 0.3 / 12.4 ± 1.0 °C (palmar/dorsal sides) and in hand 19.4 ± 0.7 / 22.7 ± 1.1 °C (palmar/dorsal sides). Snow immersion decreased all skin temperatures considerably: in comparison to dry hand, snow immersion decreased little finger temperature further by 8.4 ± 1.9 °C, forefinger by 8.0 ± 1.0 / 6.1 ± 1.0 °C and hand by 7.2 ± 1.1 / 7.0 ± 1.1 °C for 30 s after the immersion. At the end of the 3 min cold exposure, the effect of immersion was 7.0 ± 1.0 °C, 6.5 ± 0.7 / 4.7 ± 1.1 °C and 2.9 ± 0.4 / 4.4 ± 1.5 °C, respectively (figure 2). During the 3 min cold exposure after the immersion, the melted snow was evaporated almost totally and hand became almost dry.

After the cold exposure, little finger temperature was recovered first to the pre-exposure level (in 4 min at room temperature), and it even exceeded the pre-exposure level by ca. 1 °C. Forefinger reached the pre-exposure level in 7 min after the cold exposure. The temperatures in dorsal and palmar side of the hand remained ca. 2 °C below the pre-exposure level even 10 min after the cold exposure.

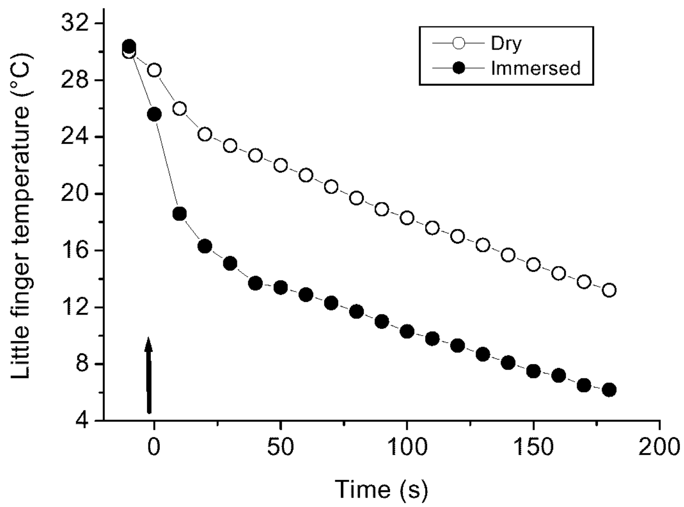

Figure 1. Little finger temperature, measured from the palmar side during cold exposure, with and without snow immersion. The arrow points the start of the ca. 2 s immersion.

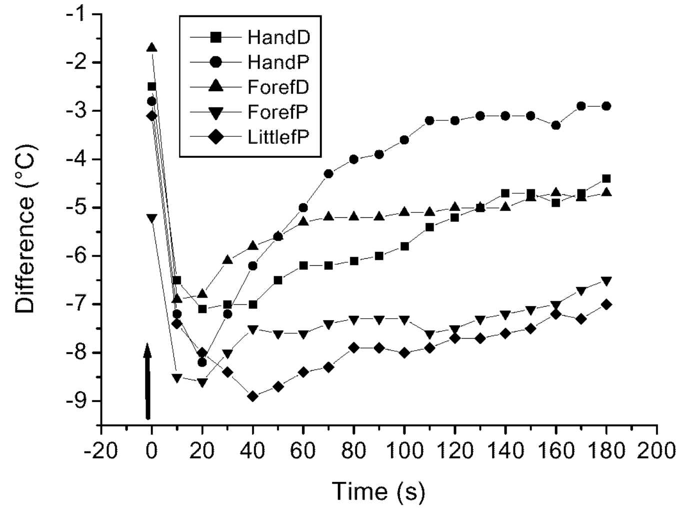

Figure 2. Temperature difference between dry and snow-immersed hand. The arrow points the start of the ca. 2 s immersion. HandD = dorsal side of the hand, HandP = palm, ForefD = dorsal side of forefinger, ForefP = palmar side of the forefinger, LittlefP = palmar side of the little finger.

Discussion

The present results emphasise the marked cooling effect of single snow immersion on hand and especially on finger temperatures. Because the cooling effect was most conspicuous almost immediately after the immersion, the heat loss due to the thawing of snow had obviously a marked role. Moreover, evaporation of the melted snow obviously increased the heat loss.

The ca. 8 °C additional decrease in finger skin temperatures by snow immersion points out how important it is to protect the hands during manual tasks in winter. Snow immersion markedly increases the risk of frostbite. If it is necessary to perform a task with bare hands, possibilities for quick rewarming of hands should be readily available. According to the prediction model of Oakley (1990), the freezing time of finger would be more than 8 min at –10 °C with 2m/s wind. Linear extrapolation of the present data suggests that the freezing time of a non-immersed little finger would be, on the average 7.7 min, and ca. 6.2 min when immersed into snow.

The increased finger skin temperatures observed during rewarming are obviously caused by cold-induced stimulation of finger circulation. If fingers are repeatedly exposed to cold, the increased circulation may protect from cooling to some extent.

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